Experiment 11 - Current Sources and Voltage Sources

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1.0 Objective

This experiment will introduce techniques for current source biasing. Several different current sources will be considered. Some requirements for current sources include high output resistance with a wide range of voltage drops and independence from external factors such as supply variation or temperature variation. The second kind of source we'll be considering is a voltage source. MOS current sources often are biased from a voltage source. An independent voltage source is important to keep a current source properly biased without any variations.

To show your understanding of the lab, your write-up should contain:

- A discussion on the different types of current sources
- A discussion on the choosing the right type of current source
- A discussion on the valid range of operation for various current sources

2.0 Prelab

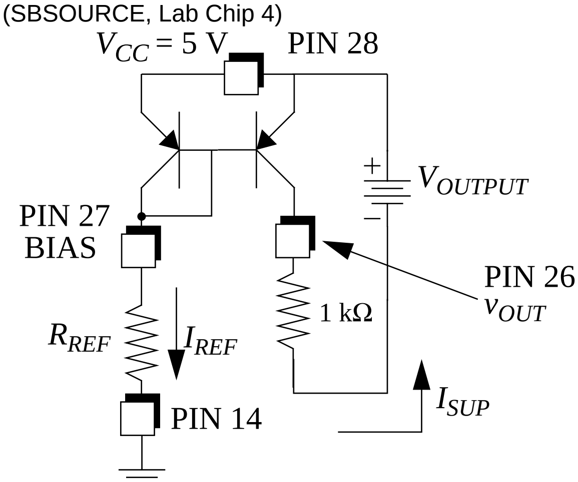
- H & S: Chapter 9.4
- For the current sources in figures 1 and 2, what is I_{REF}, I_{OUT}, the current supply's internal resistance (in terms of small signal parameters) and the minimum output voltage required to have the circuit act as a current source. Let R_{REF}=1 kΩ.
- For the circuit in figure 4, determine the current through R_{REF} if all the devices have W/L=1. Use your measured values for K_n and K_p. Let R_{REF}=1 kΩ and ignore the backgate effect.

3.0 Procedure

3.1 Simple Current Source

1. Construct the circuit in figure 1. Let R_{REF}=5 kΩ. Find and record the current I_{REF}.

FIGURE 1. Simple Current Source (SBSOURCE, Lab Chip 4)



2. Vary the output voltage from 0 to 5 V and measure the current I_{SUP} from the voltage drop across the 1 kΩ resistor. You should record several points below 0.5 V in order to observe saturation effects. Use a 100 Ω resistor if the supply voltage is unsteady.
3. Plot I_{SUP} vs. V_{OUT}. and I_{SUP} vs. V_{CC} - V_{OUT} = V_{SUP}. Compare the results with SPICE.
4. From the plot, find the output resistance.

3.2 Cascode Current Source

1. Figure 2 shows a cascode current sink from Lab Chip 5.
2. Place the Lab Chip 5 into the test fixture of the HP-4145.
3. Load the program **PCS** using the keystrokes: **[GET]** ***PCS*** **[EXE]**.
4. Connect **SMU1** to the BIAS pin and **SMU2** to the OUT pin.
5. Enter for the constant-slope current the nominal current you found in procedure 3.1.
6. Execute the program to obtain the plot of the cascode's *I-V* characteristics.
7. Using the Marker and Cursor, find the output resistance. (refer to Exp. 1 if you have forgotten how to find the slope of a line.)
8. Note the minimum operating voltage for this current source.
9. How does the cascode compare with the simple current source?
10. Obtain a hardcopy of your data.

FIGURE 2. Cascode Current Sink (CASBSINK, Lab Chip 5)

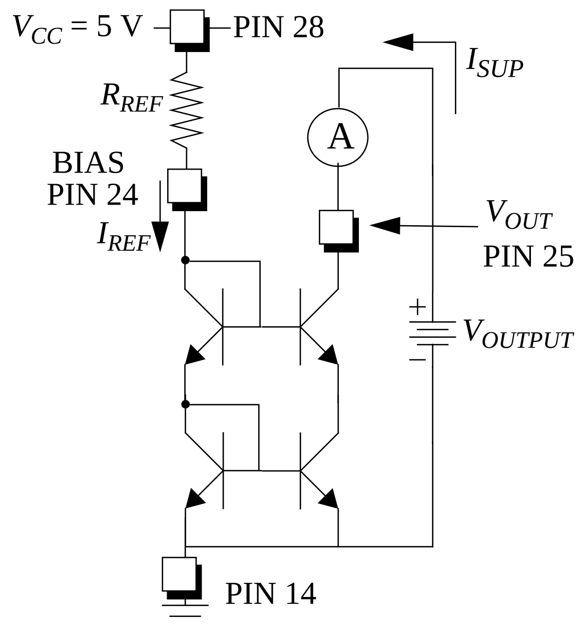
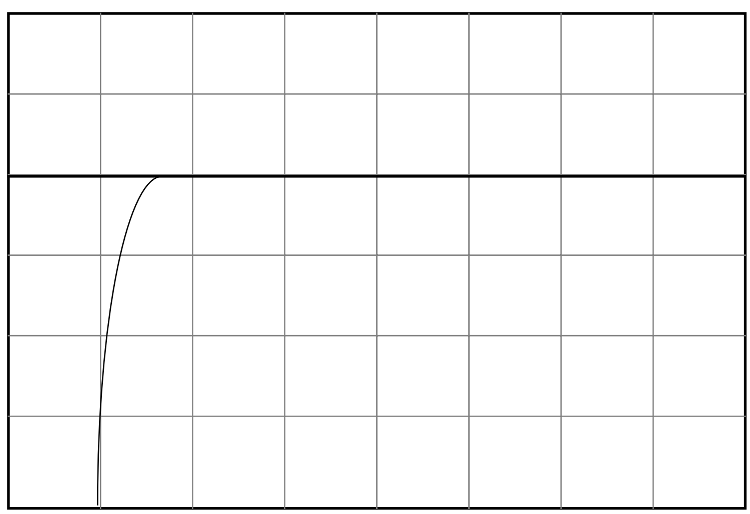


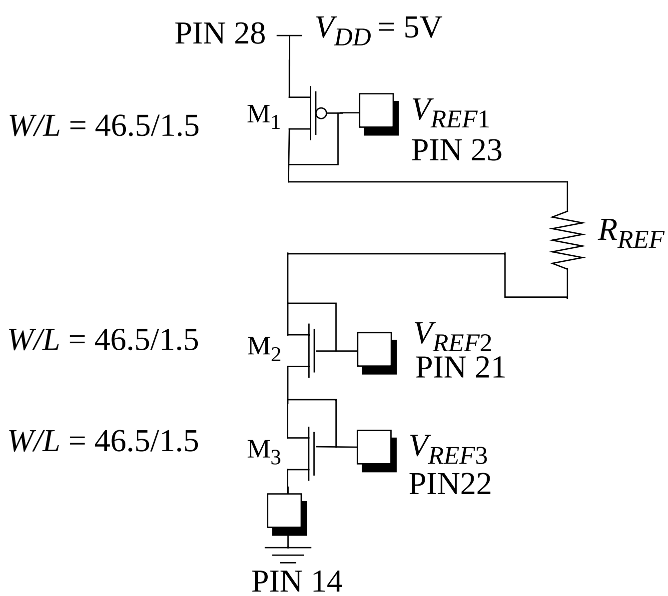
FIGURE 3. Extrapolated line to find the output resistance of the cascode current source



3.3 Totem Pole Voltage Source

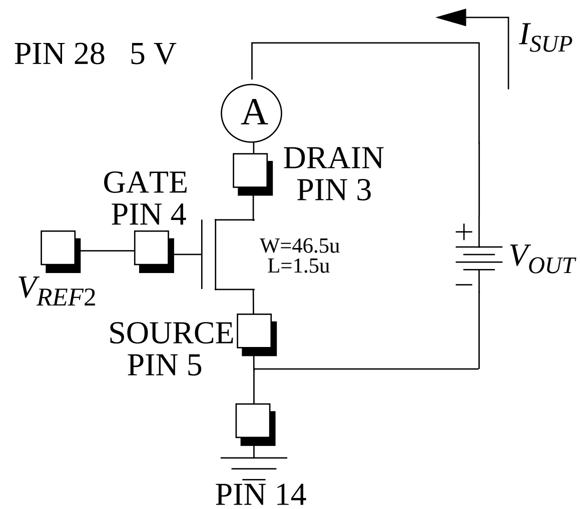
The following schematic shows a totem pole voltage source.

FIGURE 4. Totem Pole Voltage Source on Lab Chip 5



1. Construct the circuit by placing a 1 kΩ resistor for R_{REF} between V_{REF1} and V_{REF2}. Measure the drain current and the reference voltages.
2. How do the reference voltages compare with theoretical values? How can you account for the difference?
3. The reference voltages act like batteries. Their values remain constant as long as there are no leakage currents at that node. For the NMOS transistor shown in figure 5, use V_{REF2} to generate a reference current, I_{OUT}. Vary V_{OUT} and determine the minimum output voltage of this NMOS current source. What is the output resistance?
4. Replace the NMOS with one with a different *W/L* ratio on Lab Chip 1 (Drain = PIN 6, Gate = PIN 7, Source = PIN 8, and *W/L*=46.5/3) and repeat procedure 3. How do the results compare?

FIGURE 5. NMOS Transistor as a Current Source (Lab Chip 1)



4.0 Optional Experiments

4.1 Resistor Ratioed Current Source

1. Construct the current mirror shown below (devices on Lab Chip 2).

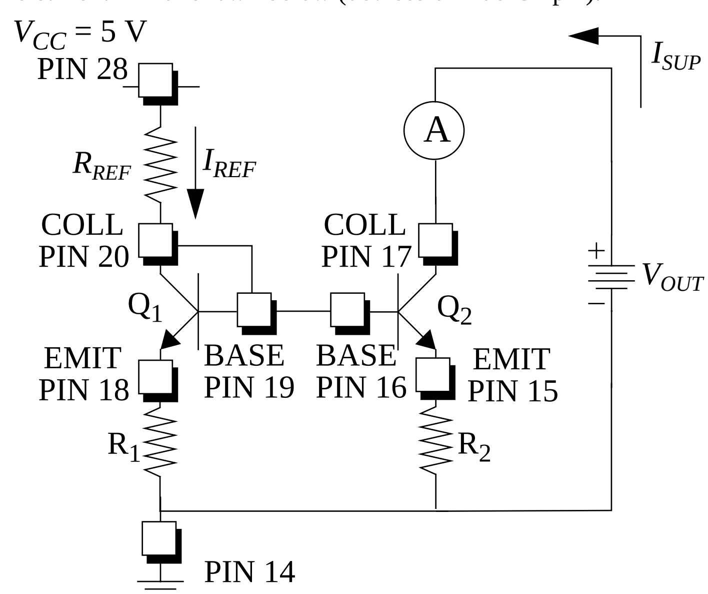


FIGURE 6. Resistor Ratioed Current Source

Let $R_1 = R_2 = 100\Omega$ and R_{REF}=5 kΩ.

2. Record values for I_{SUP}, V_{BE1} and V_{BE2}.

3. Change the value of resistor R_2 to 1 kΩ. What is I_{OUT}?

4. Now switch the resistors. What is I_{SUP} now?

5. Derive an approximate relationship between I_{SUP} and I_{REF}. Does your data follow this relationship?

6. Let R_1 = 1kΩ and R_2 be 100Ω, 3kΩ, followed by 5kΩ. This should give you better insight into how this mirror works. You need not take a detailed sweep here.